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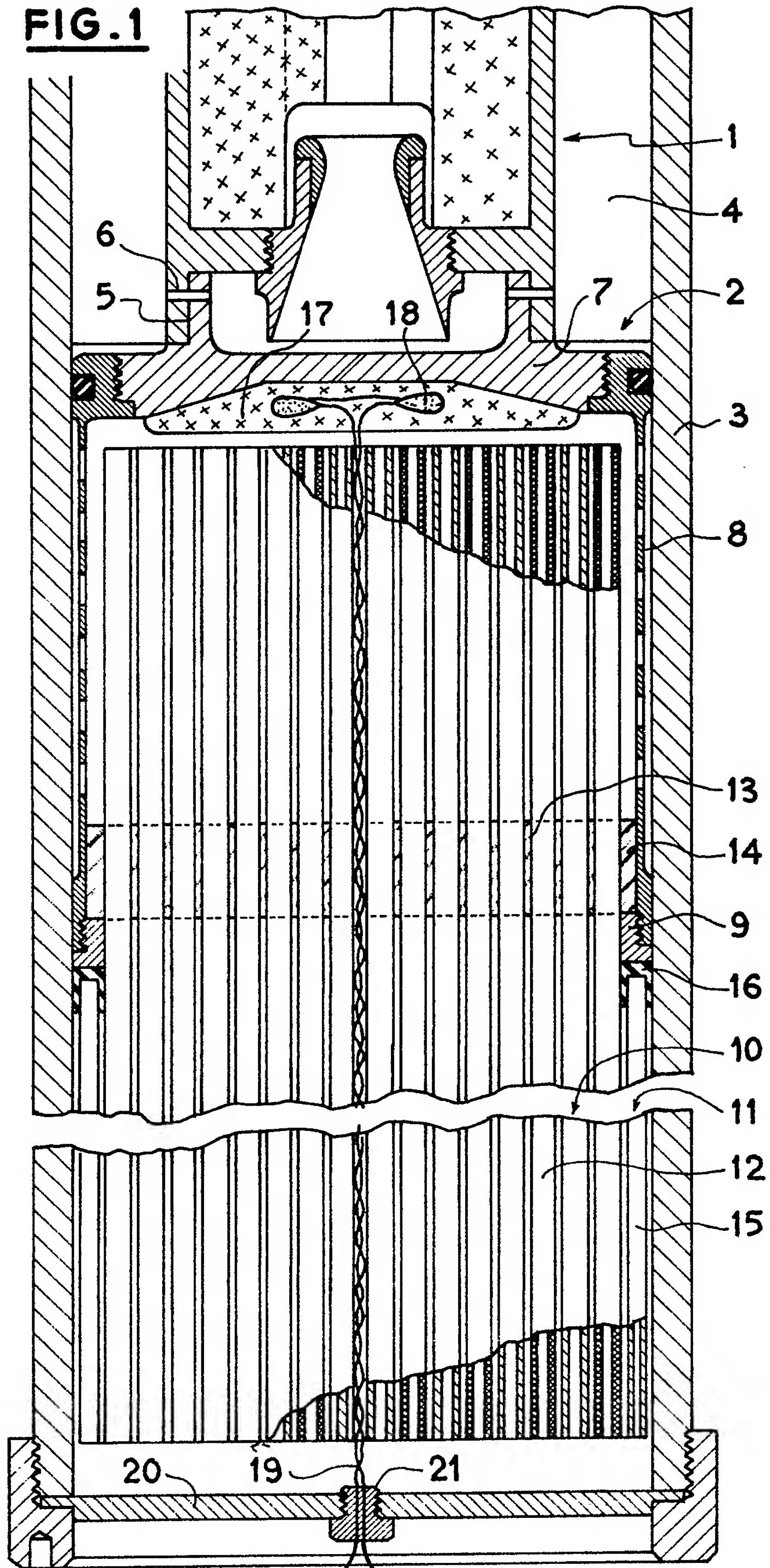
(54) **Propulsion unit and process for the acceleration of a missile**

(57) A propulsion unit 2 for the acceleration of a missile 1 comprises a body 7 connected by a shear connection 6 to a cruising stage of the missile and supporting a propellant charge consisting either of tubular elements 10, 11 stuck on an inhibiting ribbon 13 which is sprially wound or plates of propellant arranged in the form of a star, the charge being located within a cylindrical envelope formed, as shown, by a launching tube 3 without a nozzle and closed at the rear end by a frangible cover 20. The charge is initially ignited under conditions which permit a stable combustion of the propellant, the charge continuing to burn for a duration of less than one second under conditions which theoretically correspond to an unstable combustion of the propellant. Maximum and minimum values for the ignitable surface area of the propellant are specified.
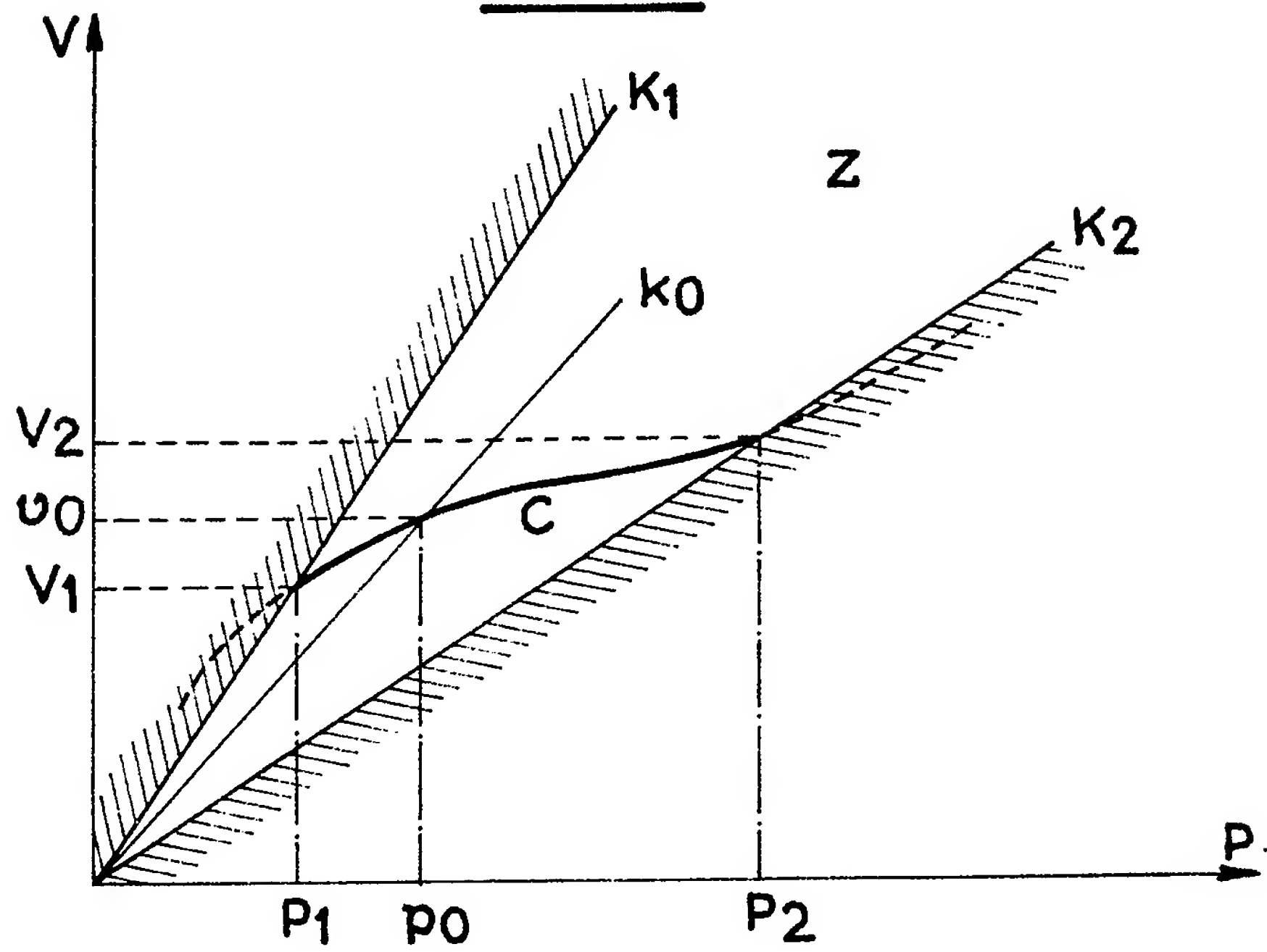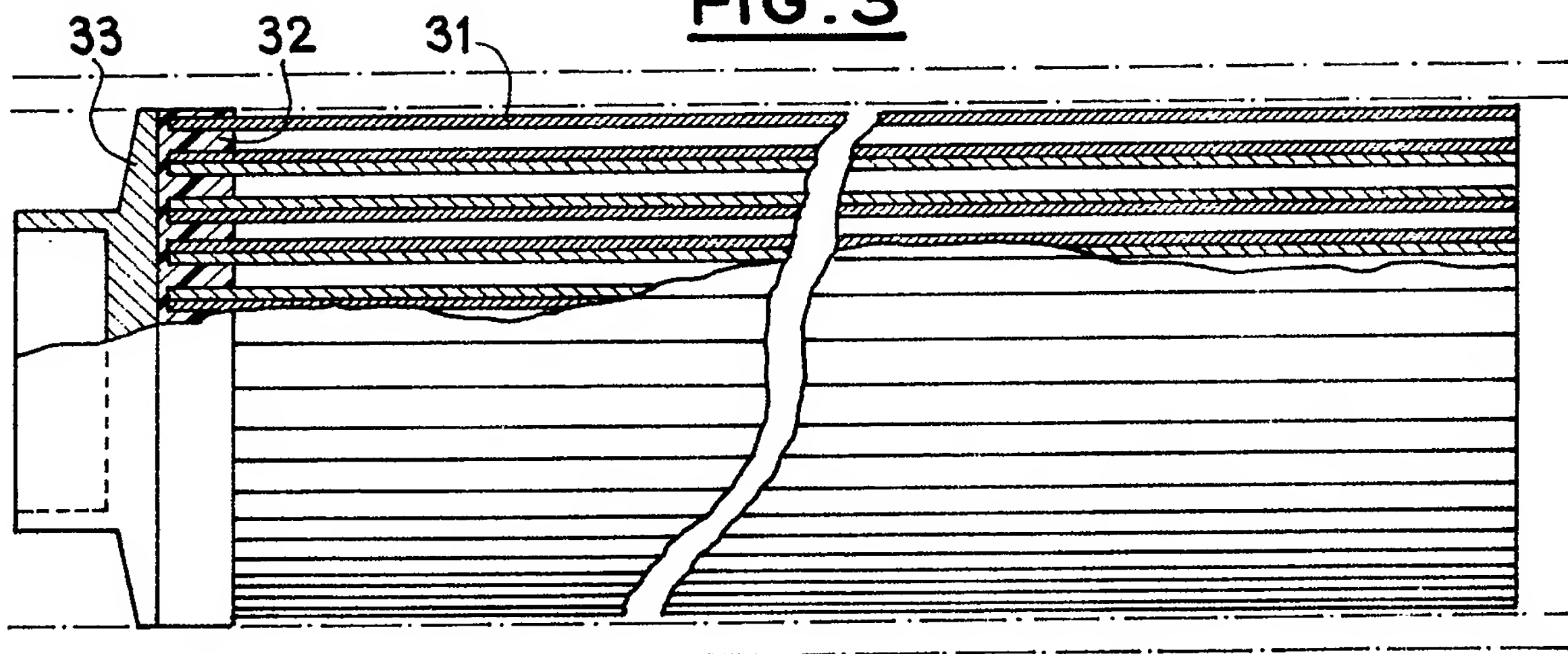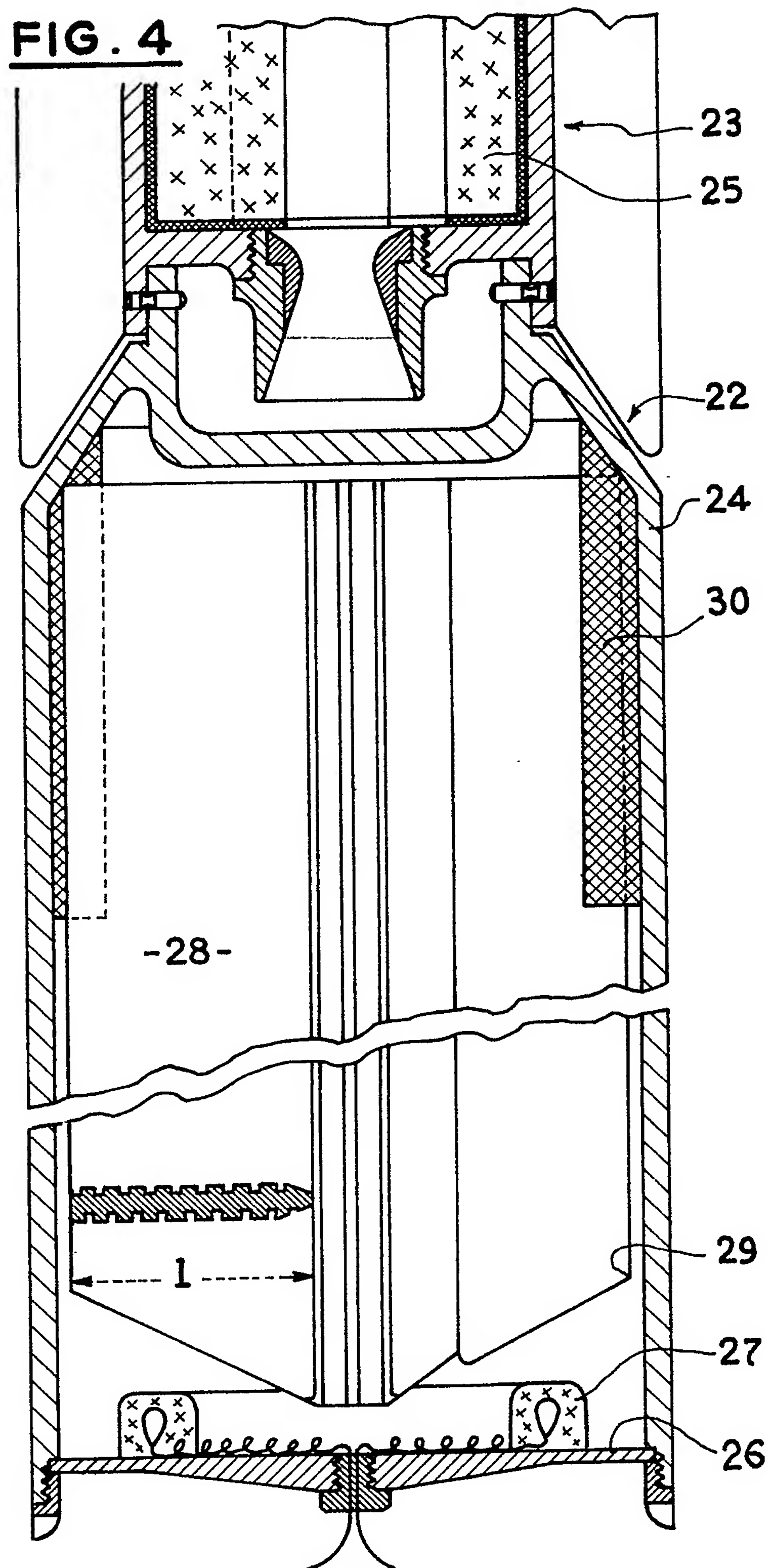
FIG.1

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FIG.1

FIG.2

FIG.3

FIG. 4

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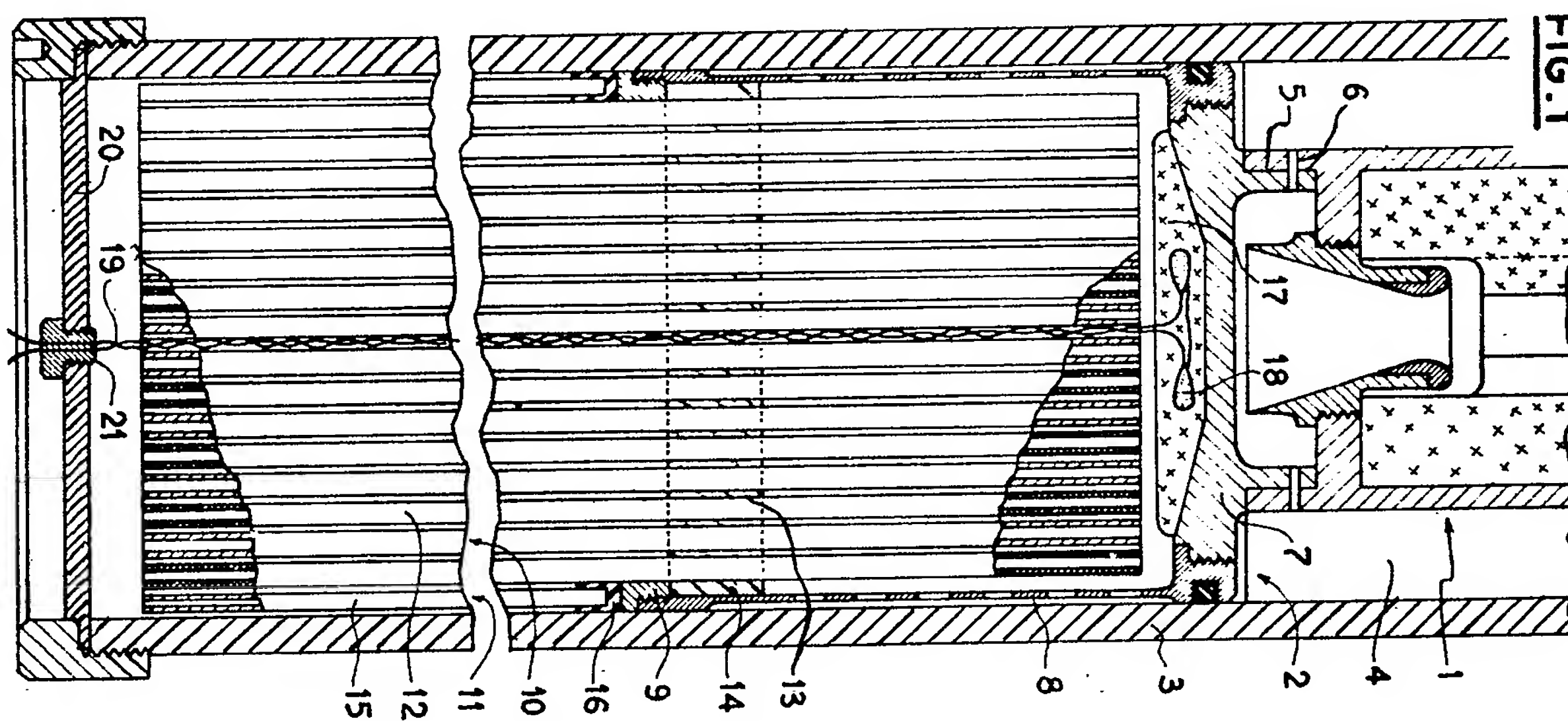
SPECIFICATION

**Propulsion unit and process for the acceler-
ation of a missile**

This invention relates to the propulsion of
missiles by means of a propellant charge
produced from solid propellant, and more
especially relates to propulsion units for the
acceleration of self-propelled missiles, in parti-
cular missiles fired from a launching tube.

Self-propelled missiles, such as guided mis-
siles or rockets, most frequently comprise two
separate stages, namely, an acceleration stage
which is subsequently released during the
flight of the missile, and a cruising stage
which contains the useful load. Although the
cruising stages always comprise a conven-
tional propulsion system including a body
outside the charge, which withstands the pres-
sure of the combustion gases and is
equipped, in its downstream part, with at
least one nozzle for the ejection of the com-
bustion gases, this is not the case of the
acceleration stages of missiles which are fired
from launching tubes. In fact, such accelera-
tion stages can comprise a propulsion system,
the body of which does not have to withstand
the pressure of the combustion gases, this
pressure being exerted instead directly on the
internal surface of the launching tube, and the
body of the propulsion system only has to
hold in place a nozzle for the ejection of the
gases, it being possible for this nozzle to be
either a conventional central nozzle, or an
annular nozzle which is formed by a free
passage between the internal surface of the
launching tube and a central bulb or an
annular bulb integral with the body of the
propulsion system. Such acceleration stages,
in which the body of the propulsion system
does not have to withstand the pressure, are
of particular value because it is possible to
lighten the body of the propulsion system,
which is then acted upon only by the pulling
force resulting from the action of the gases on
the convergent parts of the nozzles. This light-
ening of the body of the propulsion system
enables a reduction of its transverse cross-
section, which makes it possible to increase
the cross-section available for housing the
propellant charge, despite the very large longi-
tudinal pulling forces which are generated in
the acceleration stages.

As regards missiles fired from a launching
ramp or from a simple caisson, and missiles
which are fired from a launching tube but for
which the combustion time of the propellant
charge for acceleration is greater than the
time for which the missile moves in this tube,
it is necessary for the bodies of the propulsion
systems of these missiles to support both the
radial forces generated by the pressure being
exerted on the side surface of the body of the
propulsion system, and, the longitudinal

forces generated by the pressure being ex-
erted on the convergent parts of the nozzles.
This double orientation of the stresses makes
it necessary to produce a propulsion system
with a very strong body and, as a result, for a
given maximum cross-section of the missile,
the large thickness of this body required to
provide the necessary strength means a
smaller cross-section available for housing the
propellant charge. Furthermore, when the
body of the propulsion system is made of a
composite material comprising webs of high-
modulus fibres, it is necessary to provide a
large number of intersecting webs in order to
enable the body of the propulsion system to
withstand the radial and longitudinal stresses.

According to the present invention there is
provided a propulsion unit for accelerating a
self-propelled missile, comprising a body, a
propellant charge including separate elements
of propellant and carried on the body, and a
generally cylindrical envelope surrounding the
charge and capable of withstanding the pres-
sure of the gases produced by combustion of
the charge, the envelope including an opening
for the ejection of the combustion gases from
the envelope, the ignited surface area of the
charge being between minimum and maxi-
mum values obtained by multiplying the initial
free cross-section for the ejection of the gases,
measured in the region of the ends of the
elements of propellant, by the minimum and
maximum coefficients of compression for the
composition of the propellant of the elements,
and the cross-section of the ejection opening
being approximately equal to the cross-section
of the envelope portion arranged around the
propellant charge.

By avoiding longitudinal stresses which
must be withstood by the bodies of propulsion
systems for acceleration, it becomes possible
to reduce the thickness and the length of
these bodies and therefore simultaneously to
reduce the dead weight of the acceleration
stage and increase the volume available for
housing the propellant charge for acceleration.
These advantages, which are substantial for
acceleration stages in which the body of the
propulsion system constitutes the envelope
and supports the pressure of the gases, be-
come even greater for acceleration stages in
which the pressure is withstood by a launch-
ing tube, because in this case, the body of the
propulsion system can be reduced to a simple
device which carries and positions the propel-
lant charge in the launching tube and ensures
that the thrust is transferred to the cruising
stage of the missile.

The invention can be carried out by using
propellant charges of known composition and
the general shape, but the dimensional char-
acteristics of which ensure a special process of
combustion which results partly from the dis-
covery that, if a charge is initially ignited
under conditions which permit a stable com-

bustion of the propellant of this charge, it is possible for the charge to continue burning for a short period of time under conditions which theroretically correspond to an unstable com-
5 bustion of this propellant. Experiments undertaken have shown that this new process of propulsion entails only a small reduction in the total impulse produced by the combustion of the pyrotechnic charge, and that this reduc-
10 tion can be compensated by the increase in size of the propellant charge, which is made possible by the increase in the volume available for housing the propellant charge.

The advantages gained by carrying out the
15 invention become more significant, the shorter the total combustion time of the charge. Beyond a combustion time of two seconds, the new process of propulsion no longer seems to be suitable, despite the wide choice of propel-
20 lant compositions which are available.

The invention also provides a process for the acceleration of a self-propelled missile, consisting of burning a propellant charge, which comprises separate elements of propel-
25 lant and is fixed to a body of the propulsion system, in an envelope which withstands the pressure of the gases produced by the combustion of the charge and has an opening for the ejection of the combustion gases from the
30 envelope, and wherein, at the moment of ignition, the surface area of the charge is between the minimum and maximum values obtained by multiplying the initial free cross-section for the ejection of the gases, measured
35 in the region of the end of the elements of propellant, by the minimum and maximum coefficients of compression for the composition of the propellant elements, respectively, and throughout the combustion of the charge,
40 the cross-section of the ejection opening is approximately equal to the cross-section of the part of the envelope arranged around the propellant charge.

Preferably, the propulsion unit and the ac-
45 celeration process are such that, during combustion, the instantaneous surface area of combustion of the propellant charge becomes less than the minimum value obtained by multiplying the instantaneous free cross-sec-
50 tion for the ejection of the gases, measured in the region of the ends of the elements of propellant, by the minimum coefficient of compression of the propellant composition used.

55 More particularly, the geometric conformation of the elements of propellant is such that the instantaneous surface area of combustion of the charge is less than the said minimum value for a period of time which does not
60 exceed one second. The best results have been obtained with a combustion time of less than one tenth of a second, and this covers all the applications of the invention to missiles fired from a launching tube, such as artillery
65 rockets and anti-tank rockets.

According to a first possible embodiment, which is intended, on the one hand, for missiles fired from a launching ramp or from a simple caisson, and, on the other hand, for
70 missiles which are fired from a launching tube but for which the combustion time of the propellant charge is greater than the time for which the missile moves in this tube, the cylindrical envelop forms part of the body of
75 the propulsion system. It is then necessary for the opening in the body of the propulsion system to be temporarily blocked for as long as the propellant charge has not been ignited, it being possible to effect this blocking, for
80 example, either by means of a cover which can shear, in the case where the body of the propulsion system forms part of the first stage of a self-propelled missile, or by means of part of the lower stage, in the case where the body
85 of the propulsion system forms part of an intermediate stage or of the last stage of a propelled missile.

According to a second possible embodiment, the cylindrical envelop consists of an
90 element of the launching tube for the self-propelled missile, it being possible for this element to form a direct part of the temporarily blocked launching tube, or for this element to be joined to the launching tube and
95 form the container for transporting the self-propelled missile, the rear opening in this container possessing a blocking device which only frees this opening when the propellant charge is ignited. This blocking device is
100 preferably a cover which can shear along a circumference corresponding to the internal surface area of the container.

The new process of operation employed in the propulsion unit according to the invention-
105 requires the use of a propellant charge possessing a very large surface area of combustion, and, preferably, there are at least ten disjoined elements of propellant forming this charge, in the case where these elements are
110 blocks of star-shaped cross-section or grooved sheets, and at least fifty in the case where these elements are tubes of propellant. Since the flow-rate of the combustion gases is very high and the combustion gases are ejected at
115 a supersonic speed, it is advantageous, on the one hand, that the elements of propellant be arranged parallel to the side surface of the cylindrical envelope, and, on the other hand, that each element of propellant has a constant
120 transverse cross-section.

According to a particularly simple embodiment, all the elements of propellant have an identical transverse cross-section and all the elements of propellant are of identical com-
125 position; however, since the essential condition is that all the elements of propellant possess the same combustion time, it is possible to use mixed charges comprising elements of propellant of different shapes and/or of
130 different compositions. A satisfactory embodi-

ment of the invention requires the use of
propellants which simultaneously possess
good mechanical properties and a high com-
bustion speed which is greater than 10 milli-
5 metres per second, and homogeneous propel-
lants, such as propellants based on nitrocellu-
lose and on nitroglycerine, are particularly
suitable. Good mechanical properties are re-
quired in order to form a propellant charge in
10 which the elements of propellant do not con-
sist exclusively of propellant, but it should be
noted that it is possible to use weaker propel-
lants, insofar as the method of fixing the
elements of propellant to the body of the
15 propulsion system is especially adapted, for
example by increasing the number of fixing
zones over the whole length of these elements
or by strengthening these elements by means
of a rigid strap which is preferably an internal
20 strap. Composite propellants, that is to say
those consisting essentially of plastic binder
and an oxidising agent, can thus be used.
     Preferably, if the total combustion time of
the charge is greater than a few tenths of a
25 second, at least one element of propellant
possesses an instantaneous surface area of
combustion which increases during the com-
bustion of the propellant charge, these ele-
ments having an increasing surface area of
30 combustion representing at least ten per cent
of the total surface area of combustion of the
charge, and an arrangement of this kind mak-
ing it possible to limit the reduction in the
instantaneous coefficient of compression of
35 the charge. The increase in the instantaneous
surface area of combustion of the elements of
propellant can be achieved, for example, by
partial inhibition of these elements. Propellant
charges having shapes which are in them-
40 selves known are particularly suitable for car-
rying out the invention, in particular charges
using elements of propellants in the shape of
a tube of circular cross-section, or elements in
the shape of a plate, which are fixed to the
45 body of the propulsion system via a layer of
inhibiting material.
     The present invention is explained by the
following examples for which:
     Figure 1 is a view, in partial longitudinal
50 section, of the rear part of an anti-tank rocket
fired from a launching tube,
     Figure 2 is a graph showing the combustion
charactertic of a two-component propellant
composition,
55 Figure 3 is a view, in partial section, of the
propulsion element constituting the accelera-
tion stage of a self-propelled missile fired from
a launching tube, and
     Figure 4 is a view, in section, of a stage for
60 the acceleration in flight of a semi-self-pro-
pelled missile.
     With reference to Fig. 1, the rocket com-
prises a cruising stage (1) to which an acceler-
ation stage (2) is temporarily fixed, the whole
65 being placed in the cylindrical container (3)

which withstands the pressure of the gases
and is fixed to the rear of the launching tube
for the rocket. The cruising stage, which is in
itself known, possesses an external diameter
70 which is less than the internal diameter of the
launching tube, and it is wedged axially by
means of the stabilising fins (4). The two
stages are temporarily connected by means of
the cylindrical centering device (5) and the
75 four shear pins (6).
     The acceleration stage (2) comprises the
body of the propulsion system, which consists
of the front plate (7) to which is screwed the
perforated shell (8) of the device for wedging
80 the propellant charge, this shell being termi-
nated at the rear by the supporting ring (9),
on which is stuck the main charge (10), and
under which is stuck the peripheral charge
(11). The main charge consists of 300 tubular
85 strands (12) of two-component homogeneous
propellant, which are individually stuck to the
flexible inhibiting ribbon (13) which is wound
in the form of a spiral and strengthened on
the outside by means of the inhibiting ring
90 (14) stuck to the support ring (9). The periph-
eral charge consists of 85 tubular strands (15)
produced from the same propellant as that
used in the production of the tubular strands
of the main charge, and these 85 strands are
95 embedded in an annular inhibiting base-plate
(16) which is stuck under the support ring (9).
These propellant charges can be ignited by
means of the igniter which is fixed to the front
plate (7) of the body of the propulsion system
100 and consists of a sachet of ignition powder
(17), in which powder are placed two electri-
cal ignition devices (18) connected to the
electricity generator by means of the conduc-
tors (19) which pass through the main charge
105 along the centre of the spiral and pass
through the cover (20), which can shear, by
means of a leak-tight passage (21). This
cover, which can shear along a circumference
equal to the internal diameter of the container
110 (3), withstands the pressure of the gases
required for the ignition of the propellant
charges, the combustion of these charges
therefore taking place without the use of any
nozzle for the ejection of the gases.
115 Fig. 2 represents the usual shape of the
curve (C) which shows, for a given ambient
temperature, the speed of combustion (V) of a
propellant composition as a function of the
pressure (P) prevailing in the combustion
120 chamber, this graph constituting the combus-
tion characteristic of the propellant composi-
tion. On this graph, the lines K1 and K2 are
the lines of limiting compression, which de-
limit between one another the normal zone of
125 combustion (Z), the combustion of the com-
position being unstable or impossible outside
this zone. These graphs, which are well-
known to explosives experts, are determined
experimentally using combustion chambers
130 terminated by a nozzle of constant cross-

section, and the compression lines of the general equation $V = K.P$ have a coefficient K which is called the coefficient of compression of the propulsion system and is equal to the follow-
5 ing ratio: instantaneous surface area of combustion of the charge/area of the neck of the nozzle of the body of the propulsion system.
For a propellant charge of given conformation, the instantaneous coefficient of self-com-
10 pression (ki) is given by the following ratio: instantaneous surface area of combustion of the charge/free cross-section at the downstream end of the charge, and it should be noted that this coefficient ki only affects the
15 actual course of the combustion of a propellant charge placed in propulsion system comprising a nozzle insofar as it is less than the coefficient K of the propulsion system, that is to say insofar as the free cross-section at the
20 downstream end of the charge is less than the area of the neck of the nozzle of the body of the propulsion system. As soon as this condition is no longer obeyed, the propellant charge departs from its normal combustion
25 pattern and its mode of combustion is governed by the nozzle of the body of the propulsion system, the essential object of this nozzle being to keep the instantaneous coefficient K always between the limiting values K1 and
30 K2, which are determined solely by the composition of the propellant used.
According to the present invention, it has been discovered, firstly, that it is possible to produce industrially propellant charges con-
35 sisting of multiple strands of propellant, of which the initial coefficient of self-compression Ko is approximately equal to or greater than the coefficients K of the nozzle-type propulsion systems, and, secondly, that the instanta-
40 neous coefficient of self-compression ki of the charge can fall, for a short time, below the minimum coefficient of compression K1 of the propellant composition, without appreciably disturbing the combustion of these charges,
45 the combination of these two conditions therefore making it possible to omit the nozzle of the propulsion systems for acceleration, which always possess a short combustion time.
These discoveries are based on multiple
50 experiments and the following example is completely representative of the unexpected results which are derived from the two different modes of combustion, the charge in question being the main charge (10) of the missile
55 shown in Fig. 1, and this charge consisting of 300 strands having a length of 200 millimetres, an external diameter of 5 millimetres and an internal diameter of 3 millimetres, the propellant composition of these strands being
60 as follows:

nitrocellulose containing 11.7%	
of nitrogen:	54 parts
nitroglycerine:	36 parts
65 stabilisers:	2 parts

and 5 parts of combustion catalysts which make it possible to obtain, by means of the process of manufacture without solvent, the combustion characteristic at 20 degrees Centi-
70 grade, which is defined by the values:

V1 = 25 mm/second, P1 = 130 bars,
K1 = 250
V2 = 34 mm/second, P2 = 350 bars,
75 K2 = 400.

In the two comparison experiments carried out using this charge having an initial self-compression of 350, this charge is placed in a
80 cylindrical combustion chamber having an internal diameter of 101 mm and the firings are carried out at + 20° Centigrade:
According to a first conventional mode of combustion, the combustion chamber is
85 equipped with a nozzle having a neck of diameter 76.8 mm, which gives an initial coefficient of compression of 350, and the following values are recorded:

90 Maximum pressure PM = 480 bars
combustion time measured at 1/2 PM = 7 milliseconds
total combustion time measured at 5 bars = 25 milliseconds, and
95 in accordance with a second mode of combustion employing the present invention and not using any nozzle:

maximum pressure PM = 370 bars
100 combustion time measured at 1/2 PM = 7 milliseconds
total combustion time measured at 5 bars = 18 milliseconds.
These two comparison experiments show
105 the surprising advantages which can be gained with the new mode of combustion, because, in addition to the omission of the nozzle, which makes it possible to produce a propulsion system with a much lighter body,
110 the results show that, for an acceptable reduction in the total impulse, the maximum pressure recorded is substantially lower on the one hand, which makes it possible to lighten the cylindrical envelope withstanding the pres-
115 sure, and, the final combustion time at low pressure is greatly reduced on the other hand, which makes it possible either to carry out the firing from a launching tube under conditions which are much more satisfactory in the case
120 where the length of the tube is retained, or to reduce the length and the weight of the launching tube.
The course of the combustion of the charge in the acceleration stage shown in Fig. 1 is
125 slightly different from the course of the combustion in the experiment indicated above, because there is added, to the main charge (10), the peripheral charge (11) of which the 85 tubular strands have a length of 115
130 millimetres and a propellant thickness which

is equal to half the thickness of the strands of the main charge, the external surface of these strands of propellant being covered with a thin layer of an inhibiting material making it

5 possible for these 85 strands to have a surface area of combustion which increases during combustion, this reducing the degressive nature of the instantaneous coefficient of self-compression of the propellant charge during

10 combustion.

The initial coefficient of self-compression of the propellant charge is ko = 330 and the repesentative line on the characteristic of the composition does indeed lie inside the zone

15 (Z) of stable combustion, because it is located between the line representing the minimum coefficient of compression K1 and the line representing the maximum coefficient of compression K2. The theoretical initial speed of

20 combustion is vo = 29 mm/second and the theoretical initial pressure is 190 bars; however, the actual initial speed of combustion and the actual initial pressure are substantially higher than these theoretical values, this be-

25 ing due to the phenomenon of erosive combustion which appears when the propellant charge possesses a very high coefficient of self-compression. During combustion of the charge, the thickness of the strands of propel-

30 lant decreases and, as a result, the instantaneous free cross-section for ejection of the gases, measured in the region of the end of these strands, decreases greatly, whereas the surface area of combustion of the central

35 strands (10) remains constant and the surface area of combustion of the peripheral strands (12) increases slightly. The instantaneous coefficient of self-compression (ki) of the charge therefore decreases rapidly and falls to

40 a value which is very much less than the minimum coefficient of compression K1, which is equal to 250. The combustion therefore takes place in two successive stages, the first stage corresponding to ki>250 and tak-

45 ing place in the zone of stable combustion of the propellant composition, and the second phase corresponding to ki<250 and taking place in the zone of unstable combustion of the composition. This possibility of combus-

50 tion in an unstable zone is still physically unexplained at the present time, but it is certain that the transitory phenomena which are difficult to study are the cause of this possibility and that the initial erosive combus-

55 tion, and also the short duration of this second combustion stage, are necessary.

Fig. 3 shows the propulsion element of a self-propelled missile, the cruising stage of which is not shown and the launching tube of

60 which is shown as fine dot-and-dash lines. The charge, which is only shown schematically, consists of 400 strands (31) which have the same cross-section as the tubular strands of the embodiment shown in Fig. 1, but the

65 length of these strands is 240 mm, the front

ends being embedded in a base-plate (32) made of an inhibiting material, which base-plate is stuck directly to the body of the propulsion system (33), which is reduced to a

70 simple plate ensuring the transmission of the accelerating force to the cruising stage. This embodiment, which is particularly simple to produce, shows all the value of the new propulsion process which has been dis-

75 covered, because the reduction in the dead weight of the rocket is particularly large and also enables the firing to take place under better conditions.

Fig. 4 shows a further embodiment of the

80 invention, applied to the acceleration in flight of a semi-self-propelled missile which is initially fired from a barrel-type weapon which is not shown, the object of the acceleration stage (22) therefore being to effect an addi-

85 tional acceleration of the missile before ignition of the cruising stage (23). In accordance with this particular embodiment, the envelope which withstands the pressure of the gases forms the body (24) of the propulsion system,

90 which is temporarily rendered integral with the cruising stage by means of a cylindrical centering device and four grooved shear pins, the breaking of which is gauged so as to ensure that the two stages remain integral for

95 as long as the crusing propellant block (25), with a star-shaped central channel, is not ignited. The body of the propulsion system is approximately cylindrical and the cross-section of the opening for the ejection of the gases is

100 equal to the cross-section of that zone of the body of the propulsion system which is arranged around the charge, this opening being temporarily blocked by an ejectable diaphragm (26) on which an annular igniter (27)

105 is fixed. The propellant charge consists of sheets of propellant (28) arranged radially in the propulsion system, all these sheets having the same composition and the same thickness but possessing three different widths (w) so as

110 to permit the imbrication which is necessary to obtain a small initial free cross-section, as measured at the level of the end (29) of the peripheral edge of the trapezoid-shaped sheets. As shown in the three-dimensional

115 cross-section of Fig. 4, these sheets are provided on each of their faces with channels parallel to the axis of the propulsion system, and only these grooves are not covered with inhibitor, which makes it possible to obtain a

120 propellant charge having an increasing surface area of combustion enabling the reduction in the instantaneous coefficient of self-compression of this charge to be decreased. The grooves have parallel sides and a semi-cylin-

125 drical bottom and their depth is such that the frame fronts issuing from these sides meet at the same instant as the flame fronts issuing from the bottoms of the grooves in the opposite faces, which makes it possible to limit the

130 combustion residues. All the sheets of propel-

lant are laterally fixed by being embedded in the inhibiting shell (30) which is stuck to the body of the propulsion system, and intermediate supports for these sheets are provided in
5 order to improve the wedging of these sheets during storage and during the stage of launching the semi-self-propelled missile from a barrel-type weapon.

10 CLAIMS
1.   A propulsion unit for accelerating a self-propelled missile, comprising a body, a propellant charge including separate elements of propellant and carried on the body, and a
15 generally cylindrical envelope surrounding the charge and capable of withstanding the pressure of the gases produced by combustion of the charge, the envelope including an opening for the ejection of the combustion gases from
20 the envelope, the ignited surface area of the charge being between minimum and maximum values obtained by multiplying the initial free cross-section for the ejection of the gases, measured in the region of the ends of the
25 elements of propellant, by the minimum and maximum coefficients of compression for the composition of the propellant of the elements, and the cross-section of the ejection opening being approximately equal to the cross-section
30 of the envelope portion arranged around the propellant charge.
2.   A propulsion unit according to claim 1, wherein the geometric conformation of the elements of propellant is such that, during
35 combustion, the instantaneous surface area of combustion of the propellant charge becomes less than the minimum value obtained by multiplying the instantaneous free cross-section for the ejection of the gases, measured in
40 the region of the ends of the elements of propellant, by the minimum coefficient of compression of the propellant composition used.
3.   A propulsion unit according to claim 2,
45 wherein the geometric conformation of the elements of propellant is such that the instantaneous surface area of combustion of the charge is less than the said minimum value for a period of time which does not exceed
50 one second.
4.   A propulsion unit according to any one of claims 1 to 3, wherein the cylindrical envelope forms part of the body of the propulsion system.
55 5.   A propulsion unit according to claim 4, wherein the body is provided with a blocking device for closing the opening for as long as the ignition pressure of the propellant charge is not reached.
60 6.   A propulsion unit according to any one of claims 1 to 3, wherein the cylindrical envelope consists of a part of a launching tube.
7.   A propulsion unit according to claim 6, wherein the part of the tube has the form of a
65 container having a rear opening closed by a

blocking device adapted to free the opening when the ignition pressure of the propellant charge is reached.
8.   A propulsion unit according to claim 7,
70 wherein the blocking device is a frangible cover adapted to shear around a circumference corresponding to the internal surface of the container.
9.   A propulsion unit according to any one
75 of claims 1 to 3, wherein there are at least ten elements of propellant.
10.   A propulsion unit according to any one of claims 1 to 3, wherein the elements of propellant extend parallel to the surface of
80 the cylindrical envelope.
11.   A propulsion unit according to any one of claims 1 to 3, wherein each element of propellant has a constant transverse cross-section.
85 12.   A propulsion unit according to claim 11, wherein all the elements of propellant have the same transverse cross-section.
13.   A propulsion unit according to any one of claims 1 to 3, wherein all the elements
90 of propellant are of identical composition.
14.   A propulsion unit according to claim 13, wherein the elements of propellant are produced from homogeneous propellant.
15.   A propulsion unit according to any
95 one of claims 1 to 3, wherein all the elements of propellant have the same combustion time,
16.   A propulsion unit according to claim 9, wherein at least one element of propellant possesses a surface area of combustion which
100 increases during the combustion of the propellant charge.
17.   A propulsion unit according to any one of claims 10 to 16, wherein the elements of propellant are fixed to the body of the
105 propulsion system via a layer of an inhibiting material.
18.   A process for the acceleration of a self-propelled missile, consisting of burning a propellant charge, which comprises separate
110 elements of propellant and is fixed to a body of the propulsion system, in an envelope which withstands the pressure of the gases produced by the combustion of the charge and has an opening for the ejection of the
115 combustion gases from the envelope, and wherein, at the moment of ignition, the surface area of the charge is between the minimum and maximum values obtained by multiplying the initial free cross-section for the
120 ejection of the gases, measured in the region of the end of the elements of propellant, by the minimum and maximum coefficients of compression for the composition of the propellant elements, respectively, and throughout
125 the combustion of the charge, the cross-section of the ejection opening is approximately equal to the cross-section of the part of the envelope arranged around the propellant charge.
130 19.   A process according to claim 18,

wherein during a first combustion stage, the instantaneous surface area of combustion of the charge is between the minimum and maximum values defined by the instantaneous free

5 cross-section for the ejection of the gases, and during a second combustion stage, the instantaneous surface area of combustion of this charge becomes less than the minimum value obtained by multiplying the instantaneous free

10 cross-section for the ejection of the gases, measured in the region of the ends of the elements of propellant, by the minimum coefficient of compression of the propellant composition used.

15   20.   A process of acceleration according to one of claim 18 or 19, wherein a propulsion unit used for carrying out the process is in accordance with any one of claims 2 to 16.

   21.   A propulsion element of a propulsion

20 unit according to claim 6.

   22.   A propulsion unit for accelerating a self-propelled missile, substantially as herein described with reference to the accompanying drawings.

25   23.   A process for the acceleration of a self-propelled missile, substantially as herein described.